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COMPARISON BETWEEN THE SOUTH PACIFIC CONVERGENCE ZONE AND SOUTH ATLANTIC CONVERGENCE ZONE IN JANUARY 1979

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1. INTRODUCTION

Over the last two decades, studies of satellite imagery and available surface reports have documented that the South Pacific Convergence Zone (SPCZ) and South Atlantic Convergence Zone (SACZ) are two of the dominant circulation features in the Southern Hemisphere throughout much of the year. However, since both features frequently occur, at least in part, in areas which are data sparse on a routine basis, detailed analyses of their tropospheric structure have not been possible until recently. The collection of an enhanced data set during FGGE provided such an opportunity. This paper uses one of the FGGE data sets to examine and compare the energetics of the SPCZ and SACZ areas during January 1979.

Recent studies have verified that both the SPCZ and SACZ were quasi-stationary persistent features of the large-scale circulation pattern throughout most of January 1979 (e.g., Kalney and Paegle, 1983; Huang and Vincent, 1985). However, both features either disappear or weaken considerably in February (Kalney and Paegle, 1983). In fact, Huang and Vincent (1983) and the present results suggest that the decay of the SPCZ began about 25 January. Furthermore, Kalney and Mo (1985) performed a series of experiments using the GLAS GCM and initial conditions on 5 January and 4 February 1979 to forecast the existence of these wave features in January and their absence in February. They found a significant relationship in the co-existence (or lack thereof) between the SPCZ and SACZ. They also found that latent heating in the Southern Hemisphere tropics was important in maintaining the wave activity associated with the SPCZ and SACZ, whereas topography was not important.

The purpose of the present paper is to diagnose the eddy potential and eddy kinetic energy budgets of the regions containing the SPCZ and SACZ during the period, 10-27 January 1979. A full set of energy equations, including boundary transports, is used. During the period, the SPCZ was convectively active from 10-24 January and decayed from 25-27 January (Huang and Vincent, 1983), whereas the SACZ maintained its identity the entire period. Evidence of this is presented in Fig. 1 which shows the SPCZ and SACZ tropical areas that contain values of outgoing longwave radiation (OLR) $\leq 225\ \mathrm{Wm}^{-2}$. This threshold value has been used by previous investigators as an indicator of deep convective activity. In Fig. 1, OLR data have been averaged for three time periods based on observed characteristics of the SPCZ (Huang and Vincent, 1983, 1985). It is seen that the area encompassed by OLR $\leq 225\ \mathrm{Wm}^{-2}$ is slightly larger for the SPCZ than it is for the SACZ, except in the last 3-day period when the SPCZ is virtually absent. Also, from 10-24 January, it appears that the intensity level of the SPCZ convection is somewhat greater than that in the SACZ (i.e., a larger percentage of the SPCZ area contains OLR $\leq 200\ \mathrm{Wm}^{-2}$).

The present study uses a complete set of energy equations, partitioned into zonal and eddy components, to examine the energetics of the two areas shown in Fig. 1. The equations are in space domain and are the same as those given by Brennan and Vincent (1980). To conserve space, they are not repeated here; however, for convenience they are given below in (1a, b) in symbolic form. Because the areas are small, both in longitudinal and latitudinal extent, the budgets associated with the zonal forms of energy have little or no meaning. Hence, they are not presented. The eddy forms of energy are derived from a grid point's departure from the zonal average over a 5 degree latitude belt. The equations are:

$$DAE = CA - CE + GE + BAE \qquad (1a)$$

$$DKE = - CK + CE + BKE + RKE \qquad (1b)$$

where DAE and DKE are the local rate of change of eddy available potential and eddy kinetic energy, CA is the conversion of zonal available potential to eddy available potential energy, CE is the conversion of eddy available potential to eddy kinetic energy, CK is the conversion of zonal kinetic to eddy kinetic energy, BAE and BKE are the boundary transports of eddy available potential and eddy kinetic energy, GE is the generation of eddy available potential energy, and RKE is the sum of the dissipation of eddy kinetic energy (DE) and the boundary transport of eddy geopotential, BΦE (work done). All of the terms in (1a, b) were computed from the data source described below except for GE and RKE. They were calculated as the residuals in their respective equations. Thus, they not only represent the processes mentioned above, but they also absorb any errors from computed terms and contain any subgrid-scale effects.

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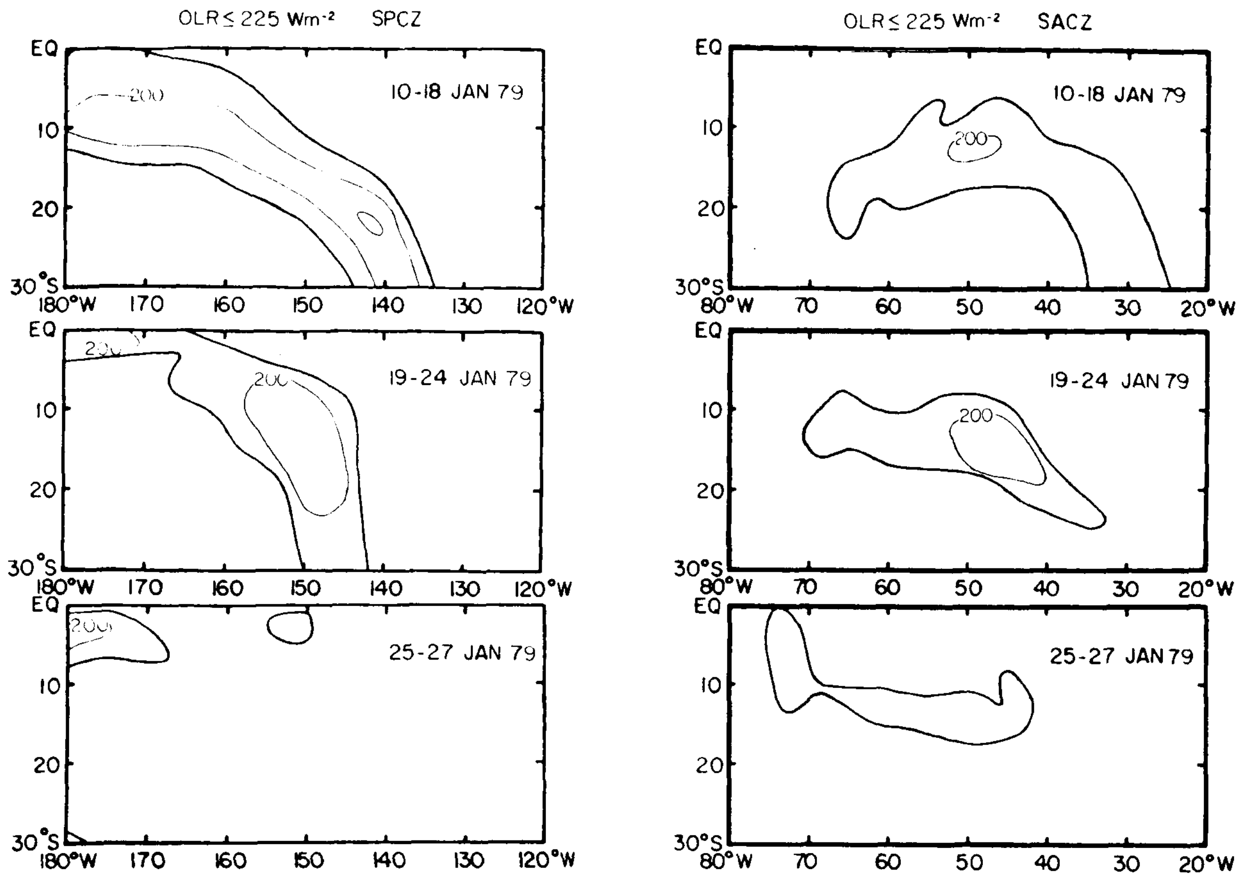

Fig. 1. Time-averaged outgoing longwave radiation (OLR) ≤ 225 Wm^{-2} for the periods shown for the SPCZ (left panels) and SACZ (right Panels).

The primary data source used in this study is the upper air data set, originally produced by ECMWF from Level III-b analyses. Some modifications were made to these data and are described by Vincent (1982) and Huang and Vincent (1985). In brief, the data have been gridded at increments of 5° lat/lon at each mandatory pressure level from 1000 to 100 mb. The variables used in the present study consist of analyzed values of mean sea level pressure, geopotential height, and horizontal wind components; temperatures computed hydrostatically from the analyzed heights, and vertical motions computed kinematically from the analyzed winds using an O'Brien (1970) adjustment scheme of no net mass flux in a column. The data for 0000 and 1200 GMT have been averaged; therefore, only daily values have been used to compute energy quantities.

2. RESULTS AND DISCUSSION

Results of the day-to-day vertically-integrated area-averaged energy terms for the AE and KE budgets of the SPCZ area are given in Fig. 2. It is seen that eddy kinetic energy content (KE) is greater than eddy available potential energy content (AE) throughout the period. AE shows a gradual, but slow decrease until after 22 January when it decreases rapidly. KE oscillates, reaching a maximum on 22 January before decreasing rapidly. Thus, both AE and KE show large losses beginning at about the time the SPCZ is in a decaying state.

The individual terms in the AE budget equation are generally small (near zero) throughout the period except for CE and the residual, GE. Based on these terms, it appears that AE is generated by diabatic heating (presumably latent heat release, since the largest values occur when the SPCZ is most convectively active) and is immediately converted to eddy kinetic energy by thermally-direct circulations. The most intense activity takes place during the first half of the period and there is a weak resurgence from about 21-24 January. After 24 January all of the budget terms are small.

The KE budget terms in Fig. 2 show that the primary sink for the source due to CE is RKE. Although BΦE is not shown because of its sensitivity to small errors, values were computed and the term was found to be a source of KE at all times, except for one day (the maximum value obtained was 2.9 Wm^{-2} and values generally were between 1 and 2 Wm^{-2}). Thus, it appears that the dissipation portion of RKE was an important sink and that the primary energy cycle consisted of a generation of AE, a conversion of AE to KE and a dissipation of KE, with the possibility that BΦE was also a main source of KE. Nonetheless, at times it is seen that the CK conversion and the BKE boundary flux make important contributions to the KE budget.

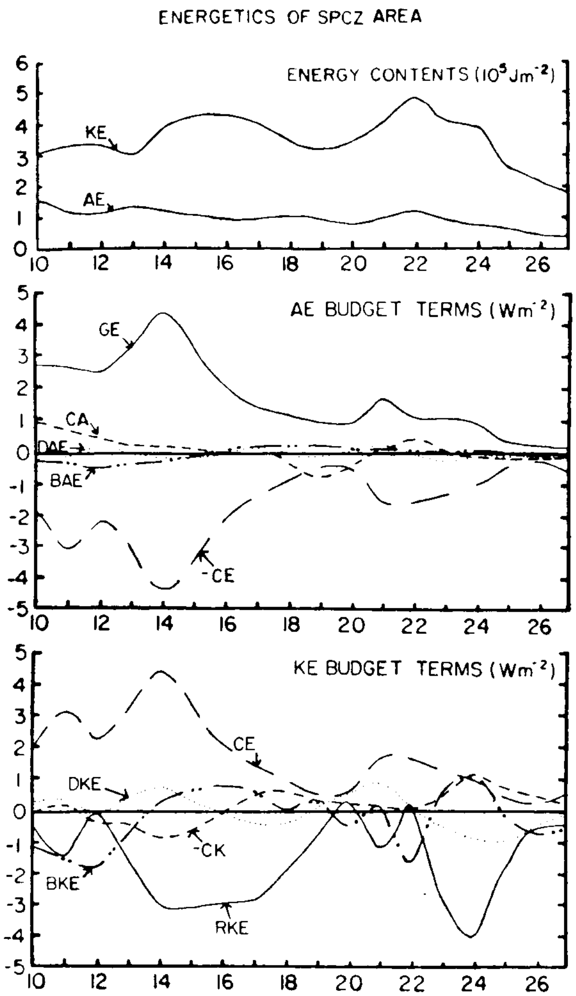

Fig. 2. Time series of space domain eddy available potential and eddy kinetic energy contents and budget terms for the SPCZ area for 10-27 January 1979.

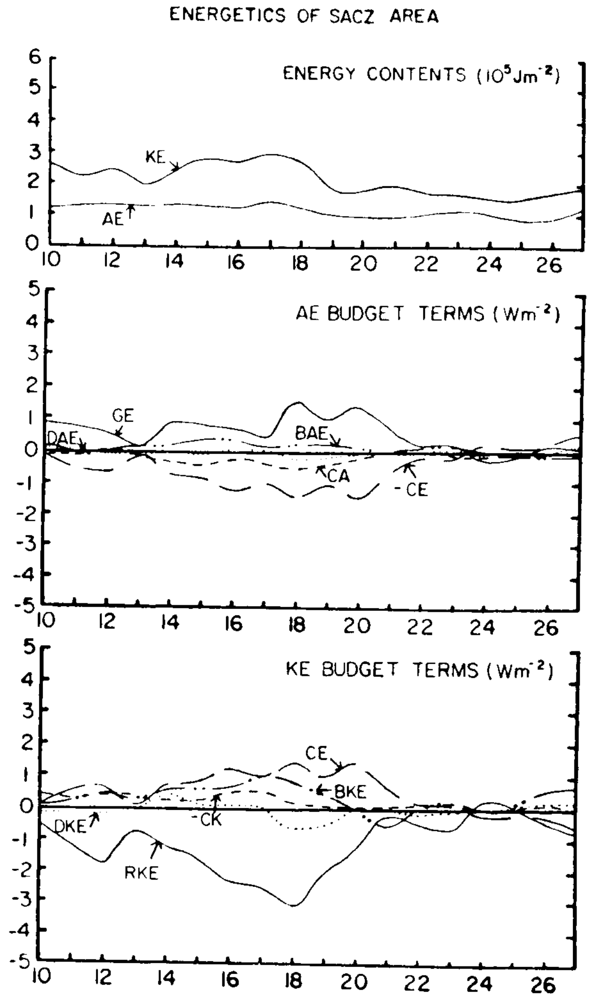

Fig. 3. Time series of space domain eddy available potential and eddy kinetic energy contents and budget terms for the SACZ area for 10-27 January 1979.

Figure 3 shows the time sequence of the AE and KE budgets for the SACZ area. As for the SPCZ area, the values of KE content within the SACZ exceed those of AE content. Although the magnitudes of AE are nearly the same in each area, values of KE in the SACZ are approximately 50% less than those in the SPCZ. Also, there is some indication of a weak decrease in both AE and KE in the SACZ near the middle of the period. In contrast to the SPCZ, there is not a decrease in either AE or KE at the end of the period. The latter fact is in agreement with the respective levels of convective activity as indicated by the OLR charts in Fig. 1.

The individual energy budget terms in Fig. 3 are generally less than their counterparts in Fig. 2. Nevertheless, the AE budget results for the SACZ are similar to those for the SPCZ in that the primary balance is between GE as a source and CE as a sink. In the KE budget for the SACZ, however, the balance is not necessarily between CE and RKE as was the case in the SPCZ. Frequently, the boundary flux term, BKE, acts as an important source of energy, together with CE, to offset the sink due to dissipation (as for the SPCZ, BKE values in the SACZ were positive and generally 1-2 Wm^{-2}).

As noted in the Introduction, Huang and Vincent (1983) found it appropriate and meaningful to composite the results for the SPCZ area into three time groups, each based on different stages of the SPCZ convective activity. The energy cycles for each of these stages is shown in Fig. 4. For comparison, the same three periods were used to composite the SACZ results, which also are shown in Fig. 4. In the first period, 10-18 January, the main flow of energy in the SPCZ consists a generation of AE by diabatic heating, a conversion of AE to KE by thermally-direct convections, and a loss of KE, presumably due to dissipation. The remaining terms do not make significant contributions. In the SACZ a similar cycle exists, however, CK and BKE represent additional sources of KE which are important. It is interesting to note that an

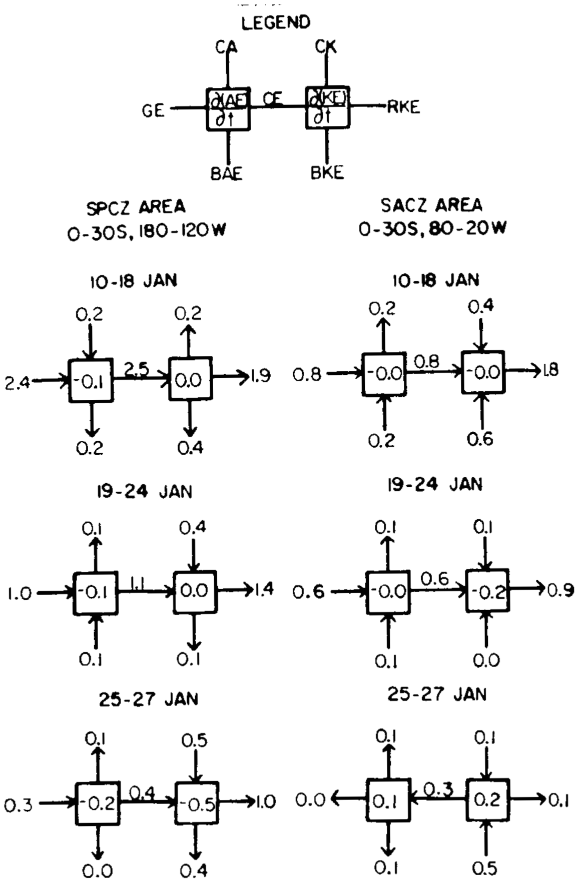

Fig. 4. Time-averaged space domain budgets of eddy available potential and eddy kinetic energy for the SPCZ and SACZ areas for the periods shown.

export of KE takes place from the SPCZ, while an import occurs within the SACZ, each at about 0.5 Wm^{-2}. Perhaps, some of the eddy kinetic energy from the SPCZ is helping to maintain the KE content in the SACZ. In this context, it's worth noting that a GCM experiment by Kalney and Mo (1985) showed that latent heating in the South Pacific had an important bearing on the strength of the SACZ. Obviously, the interaction between the SPCZ and SACZ requires further study.

During the second period, 19-24 January, the main energy cycle in both convergence zones consists of a generation of AE, conversion to KE by CE and a loss of KE due to RKE. Boundary transports and other conversions are not important. As for the first period, the intensity of the energy cycle is greatest in the SPCZ. In the last period, 25-27 January, the energy transformations in both regions are considerably weaker than in previous periods. In the SPCZ there is an insitu loss of KE which appears to be due, in part, to a gradual weakening with time of the conversion by CE. The satellite imagery shown in Fig. 1 verifies that deep convection is no longer present over much of the South Pacific, hence there is no source of AE through latent heating. This not only has a direct impact on the reservoir of AE, which can become available for conversion to KE, but also indirectly affects one of the primary mechanisms responsible for thermally-direct circulations (i.e., warm rising due to latent heating). Again, as in the first period, the export of KE from the SPCZ is approximately equal to the import into the SACZ, and these values of BKE make significant contributions to the KE budgets of their respective regions.

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